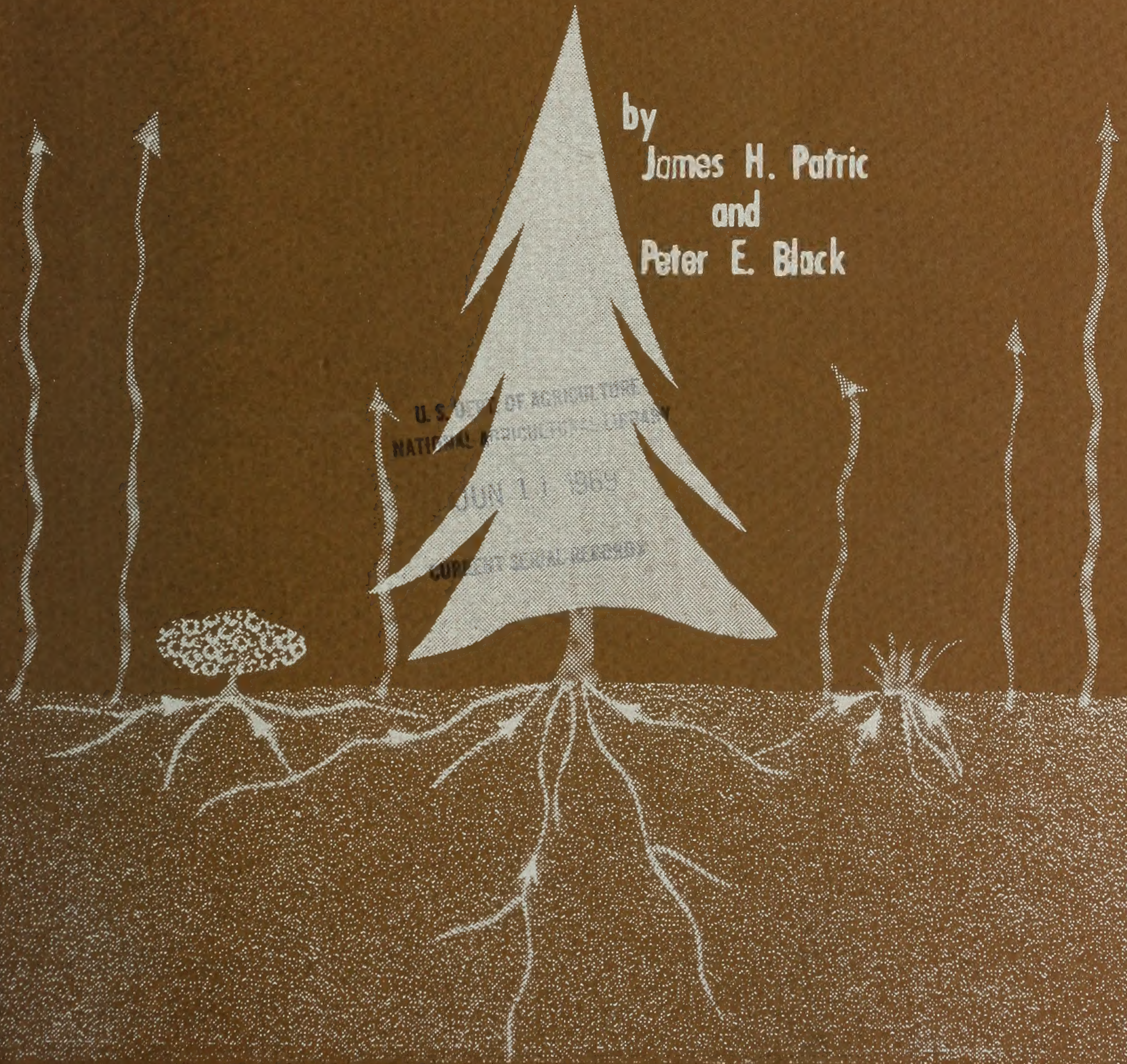
Potential Evapotranspiration and Climate in Alaska by Thornthwaite's Classification

by
James H. Patric
and
Peter E. Black



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ABOUT THE AUTHORS

Patric was hydrologist at the Institute of Northern Forestry, Juneau, Alaska, and is now project leader at Northeastern Forest Experiment Station, Parsons, West Virginia. Black is Assistant Professor of Watershed Management, State University of New York, College of Forestry, at Syracuse University, Syracuse, New York.

INTRODUCTION

Long ago, Fernow (1893)[1/] wrote concerning "the desirability of utilizing the Weather Bureau, the various agricultural experiment stations, and other forces, in forming a systematic service of water statistics, and in making a careful survey of the conditions of water supplies, which may serve as a basis for the application of rational principles of water management." Over the intervening years, many of these statistics have been amassed for other States, but many still are unavailable for Alaska. This report is a step for Alaska along the path pointed out by Fernow.

Although Alaska has about 200 currently active climatological stations, it has only 0.03 rain gage per 100 square miles, or about one-tenth the gage density for conterminous United States. This density is inadequate for realistic maps of precipitation, temperature, or runoff. Nevertheless, the U.S. Weather Bureau is accumulating a large and growing record of precipitation and temperature over the State, and the U.S. Geological Survey heads an expanding stream-gaging program. There has been less attention to evaporative losses which determine differences between precipitation income and water available for human needs. As Thornthwaite (1948) pointed out, wet and dry climates are determined neither by total nor seasonal precipitation but by the relation of precipitation to the evaporative demand. For example, precipitation amounts are nearly equal in California's Mojave Desert and in Alaska's forested and frequently boggy interior. The important and often overlooked difference between climates of these regions is the amount and timing of the evaporative demand--over 100 inches yearlong on the Mojave; only about one-sixth as much during summer in Alaska's interior.

The evaporative demand usually is established at climatic stations containing evaporation pans and associated meteorological instruments requiring regular observation and service by trained personnel. Before 1963, there were only two evaporation pans in Alaska; since then, four more have been installed and others are planned. Even this severalfold expansion of evaporation measurement constitutes a minute sample in a State one-fifth the area of the 48 conterminous States. Lacking direct measurement of evaporation, one can estimate evaporative losses from weather data which have been routinely obtained at hundreds of climatic stations.

The importance of the evaporative loss is attested by the development of many formulas for estimating it from these more easily obtained climatic data. The large number of formulas also attests that none is wholly suited to its purpose. Penman's (1948) equation is accepted as best founded theoretically, but requiring sunshine, humidity, and wind data which are reported at only four climatic stations in Alaska. Papadakis (1961) fitted climate for a few Alaska stations into his worldwide classification. Thornthwaite's (1948) equation has

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[1/] Names and dates in parentheses refer to Literature Cited, p. 27.

probably been tested more widely than any other. Penman (1956) remarked that "considering it inherent simplicity and obvious limitations, the [Thornthwaite] method does surprisingly well." Because it requires only the simplest climatic data to provide reasonably reliable estimates of evapotranspiration, Thornthwaite's method was chosen for this study.

All of the previously mentioned equations provide estimates of potential evapotranspiration (PET)--water losses from fully vegetated land surfaces always abundantly supplied with soil moisture. Some equations, including Thornthwaite's, permit estimates of actual evapotranspiration (AET)--water losses from land surfaces under conditions of natural rainfall and soil moisture utilization. The concept of PET has proven especially useful since, on the basis of available heat energy, it sets a ceiling above which water losses to the atmosphere ordinarily cannot occur. PET permits hydrologists and engineers to estimate evaporative losses from lakes and rivers; agronomists and foresters to relate plant water needs to available soil moisture. Penman (1963) has described these concepts, their uses, and some of their limitations. In addition to estimates of potential and actual evapotranspiration, Thornthwaite's method provides estimates of streamflow and a quantitative method for the classification of climates.

Only a few comparisons of estimated with measured PET are known for Alaska and northwestern Canada. At Barrow, Alaska, Mather and Thornthwaite (1958) used heat balance to compute average daily PET of 1.24 millimeters as opposed to 1.20 millimeters measured from small evapotranspirometers. Close agreement was found between several estimates of PET and soil moisture loss under irrigated grass at the Alaska Agricultural Experiment Station in Palmer.[2/] Sanderson (1950) showed close agreement between PET measurements and estimates by Thornthwaite's method at Norman Wells, Northwest Territory, Canada. Brown (1965) computed annual PET of 24.75 inches at Norman Wells but measured only 19.41 inches, using some of Sanderson's equipment.

METHODS

The climates of Alaska were determined by procedures described at length by Thornthwaite (1948) and by Thornthwaite and Mather (1955). Essentially, water availability (precipitation) is compared with water need (PET). Where precipitation exceeds PET, the climate is humid. Where PET exceeds precipitation, the climate is arid. Indexes of humidity (Ih) and aridity (Ia) are expressed as percentages in the relations:

$$Ih = \frac{100(\text{precipitation})}{\text{PET}} \quad \text{and} \quad Ia = \frac{100(\text{PET-AET})}{\text{PET}}$$

2/ Personal communication from Neil Michelson, soil physicist, Alaska Agricultural Experimental Station, Palmer, Alaska.

The humidity index has more weight than the aridity index in the moisture index (Im) calculation:

$$Im = Ih - 0.6\,(Ia)$$

Thornthwaite (1948) justified the coefficient 0.6 in the Im calculation by reasoning that a surplus of 6 inches of precipitation in one year counteracted a deficiency of 10 inches in another year. This assumption recognized that deep-rooted perennial plants were not totally dependent on rainfall to replenish soil moisture during the growing season but grew at reduced transpiration rates on moisture stored in the soil during previous seasons. This reasoning seems appropriate at those places in Alaska where snowmelt annually replenishes soil moisture and natural vegetation seldom shows evidence of prolonged soil moisture deficit. The influence of annually thawing permafrost on plant-water relations is not known.

Annual summaries of climatic data for Alaska (U.S. Weather Bureau 1916-66) provided most of the requisite precipitation and temperature data. Other sources included old descriptions of Alaska climate, publications by the Canada Department of Transport,[3/] Thompson,[4/] Potter,[5/] and the U.S. Weather Bureau files at Anchorage. Altogether, climatic records were obtained for 315 stations in Alaska, the coastal islands, and nearby Canada. These records varied in length from 1 year at several stations to about 100 years at Sitka. Estimates of available soil moisture were inferred from soil maps of Alaska (Kellogg and Nygard 1951) when more specific information was unavailable.

Water balances were computed manually from Thornthwaite and Mather instructions (1957) for each climatic station. Temperature and precipitation data for 207 of these stations also were processed in a computer program developed by Black (1967), which utilizes continuous functions rather than incremental tables. Figure 1, a preliminary example based on only 4 years of

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[3/] Canada Department of Transport, Meteorological Branch. Temperature normals for British Columbia. CDS #3-65, 10 pp. (Mimeogr.) 1965.

Canada Department of Transport, Meteorological Branch. Precipitation normals for British Columbia. CDS #8-65, 15 pp. (Mimeogr.) 1965.

Canada Department of Transport, Meteorological Branch. Precipitation normals for the Yukon and Northwest Territories. CDS #12-65, 7 pp. (Mimeogr.) 1965.

[4/] Thompson, H. A. Temperature normals, averages and extremes in Yukon Territory during the period 1931 to 1960. Can. Dep. Transp., Meteorol. Br., CDS #1-62, 9 pp. (Mimeogr.) 1962.

[5/] Potter, J. G. A catalogue of climatological stations in the Yukon and Northwest Territories. 21 pp. (Mimeogr.) Can. Dep. Transp., Climatol. Div., Meteorol. Br., 315 Bloor St. West, Toronto 5, Ont. 1965.

climatic data from Juneau Airport, illustrates a computer-produced table of water balance. Results by both manual and computer methods usually agreed closely; *t*-testing a random sample of 52 PET estimates showed no significant differences between results by either method. Climates were classified by applying the estimated PET in procedures described by Thornthwaite (1948).

MEAN ANNUAL WATER BALANCE

VERSION		WEATHER BUREAU STATION NO. 4100
SILVICULTURE GU-101 1966	1957 TO 1960	STREAMFLOW GAGE NO. 0
WBMEAN	LATITUDE 58N	NUMBER OF YEARS OF RECORD 4
THORNTHWAITE AND MATHER 1957		SOIL STORAGE IN MILLIMETERS 257

DATA IN MM., UNLESS SPECIFIED

COMPONENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TDEGF	24.8	28.5	32.9	40.2	47.9	54.4	55.4	54.5	49.3	41.7	35.1	32.1	41.4
PPTIN	2.8	3.0	3.0	3.0	3.0	2.2	4.7	4.0	6.2	7.1	6.2	6.1	51.3
AROIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TDEGC	-3.9	-1.8	.5	4.6	8.8	12.5	13.0	12.5	9.6	5.4	1.7	0.0	
HEATI	0.0	0.0	0.0	.9	2.4	4.0	4.2	4.0	2.7	1.1	.2	0.0	19.5
UNPET	0	0	0	1	2	3	3	3	2	1	1	0	
CORFA	23	24	31	34	40	40	40	37	32	28	23	21	
POTET	0	0	6	39	77	103	107	94	66	37	12	0	540
PPTMM	71	77	76	77	75	57	120	101	157	180	157	155	1303
P-PET	71	77	70	38	0	-45	13	6	91	143	144	155	762
ACPWL	0	0	0			-46	0	0	0				
STRGE	328	406	257	257	256	215	228	234	257	257	257	257	
DELTA	0	0	0			-40	13	6	23	0	0	0	
ACTET	0	0	6	39	77	98	107	94	66	37	12	0	536
DEFIC	0	0	0			5	0	0	0				5
SURPL	0	0	70	38	0	0	0	0	68	143	144	155	618
WATRO	68	34	52	45	22	11	6	3	35	89	117	136	618
SNORO	0	0	15	67	33	17	8	4	2	1	1	0	148
TROMM	68	34	67	112	56	28	14	7	37	90	117	136	766
TROIN	2.7	1.3	2.6	4.4	2.2	1.1	.6	.3	1.5	3.6	4.6	5.4	30.2

Figure 1.--*Computer output, complete water balance, for Juneau Airport, Alaska.*

RESULTS

Table 1 lists, alphabetically, all of the stations for which data were available to calculate PET and to classify climate. Alaska's climate (A $B'_1rb'_1$; i.e. perhumid, first mesothermal,[6] no season of rainfall deficit, temperature efficiency normal to first mesothermal) occurs in sheltered places close to the Pacific Ocean from Sitka southward. Within this region, mean annual temperature may exceed 45° F. and precipitation, usually rain, often exceeds 100 inches per year. This is Alaska's only mesothermal climate, a type sometimes compared to that of the less rainy central Atlantic States. The area, extending from Prince Rupert, British Columbia, and along the entire Pacific coast well out into the Aleutian Islands, has as much rainfall but is cooler (A $C'_2rc'_2$; perhumid, warm microthermal, no season of rainfall deficit, temperature efficiency normal to warm microthermal). Here, annual temperatures average nearer 40° F., similar to the less rainy climate of coastal Maine.

There are no broad expanses of humid (B) climate; apparently, the belt of humid climate is the transition between prevalent coastal and interior conditions. Thus, Skagway ($B_1C'_2sc'_2$; humid, warm microthermal, moderate summer water deficiency, temperature efficiency normal to warm microthermal) is drier than nearby coastal stations, and Nome ($B_1C'_1rc'_1$; humid, cold microthermal, little or no water deficiency, temperature efficiency normal to cold microthermal) is wetter than nearby interior stations.

The Matanuska Valley, Alaska's agricultural center, has a drier climate ($C_1C'_2dc'_2$; i.e., dry subhumid, warm microthermal, little or no water surplus, thermal efficiency normal to warm microthermal). Mean annual temperatures are about 35° F., similar to northern Wisconsin and Minnesota.

The "typical" Alaska climate (D $C'_2dc'_2$; i.e., semiarid, warm microthermal, little or no rainfall surplus, temperature efficiency normal to warm microthermal) centers in the upper Yukon, Copper, and Susitna River valleys. Annual precipitation consists of about 2 feet of snow and 8 or 10 inches of summer rain. Mean annual temperatures range from 20° to 25° F. and winter temperature may fall to -60° F. This climate sometimes is compared with that of the Yellowstone area in Wyoming. A similarly dry but colder climate (D $C'_1dc'_1$; semiarid, cold microthermal, little or no rainfall surplus, temperature efficiency normal to cold microthermal) is more widespread, extending from the Seward Peninsula eastward into Yukon Territory, from the Brooks Range southeast into British Columbia.

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[6] The terms "mesothermal," "microthermal," and "tundra," as used in this classification, express decreasing lengths and temperatures of growing seasons. The terms "cold" and "warm" have been used in conjunction with microthermal climates because they are more descriptive than the conventionally used terms "first" and "second."

Table 1.--*Location and climatic description for*

Station name[1/]	Eleva-tion	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapo-transpiration (PET)
	Feet			Degrees F.	Inches	Inches
Adak*[3/]	34	51°53'	176°39'	40.2	57.9	20.94
Afognak	40	58°00'	152°47'	39.9	51.42	19.25
Aishihik*	3,170	61°39'	137°29'	24.5	9.88	21.42
Akiak*	21	60°55'	161°23'	27.3	17.55	16.54
Akulurak	40	62°30'	164°25'	27.3	14.87	15.02
Aleknagik	55	59°18'	158°54'	32.8	36.07	17.15
Alice Arm*	104	55°30'	129°30'	32.7	80.05	15.08
Allakaket*	600	66°35'	152°44'	20.5	13.78	16.97
Alpine Inn	455	61°43'	148°54'	33.4	17.36	18.49
Amchitka*	226	51°24'	179°15'E.	38.7	35.68	19.49
Anaktuvuk Pass*	2,100	68°10'	151°46'	13.2	10.68	11.34
Anchorage*	118	61°13'	149°52'	35.3	14.27	19.25
Angoon*	35	57°30'	134°35'	40.7	39.10	21.10
Aniak*	81	61°35'	159°36'	28.3	20.58	17.17
Annette*	18	55°04'	131°39'	45.6	96.59	23.70
Annex Creek*	24	58°19'	134°06'	39.8	109.11	20.91
Atka*	36	52°13'	174°12'	40.1	59.64	20.55
Atlin*	2,200	59°35'	133°39'	24.8	10.95	12.91
Attu	59	52°50'	173°11'E.	38.8	71.17	18.96
Auke Bay	35	58°24'	134°40'	41.4	58.33	17.79
Baranof*	20	57°08'	134°50'	41.5	151.68	20.98
Barrow*	22	71°18'	156°47'	9.7	4.36	7.01
Barter Island*	39	70°08'	143°38'	10.4	6.28	7.44
Bear Cove	50	59°43'	151°05'	35.3	25.74	17.47
Beaver Falls*	35	55°23'	131°28'	44.2	153.73	22.83
Bell Island*	10	55°55'	131°35'	43.6	108.67	22.24
Bering Island*	20	52°12'	165°55'E.	32.9	21.30	16.54
Bethel*	15	60°47'	161°43'	29.6	18.17	16.81
Bettles*	666	66°54'	151°31'	22.1	14.01	16.85
Big Delta*	1,268	64°08'	155°44'	27.4	11.54	18.15
Big Lake	130	61°32'	149°55'	32.8	20.9	18.06
Bonanza Mine	5,800	61°31'	142°53'	24.7	22.41	6.35
Boundary*	2,600	64°04'	141°07'	22.3	13.22	16.30
Broad Pass	2,127	63°12'	149°15'	28.3	11.4	16.69
Brooks Lake	44	58°33'	155°49'	35.4	21.18	17.29
Calder*	20	56°10'	132°27'	43.1	112.26	22.20
Candle*	24	65°56'	161°55'	20.3	9.02	14.61
Canyon Village	990	67°09'	141°05'	15.7	10.54	15.53
Cape	131	53°23'	167°54'	39.0	46.57	18.32
Cape Decision	39	56°00'	134°08'	43.7	76.49	21.73
Cape Hinchinbrook	185	60°14'	146°39'	41.6	83.30	19.07
Cape Lisburne	45	68°52'	166°08'	17.0	14.53	10.33
Cape Newenham	475	58°40'	162°10'	32.1	42.61	14.50
Cape Romanzof*	7	61°47'	166°07'	28.7	27.14	14.80

NOTE: See footnotes at end of table.

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\,(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type[2/]
Inches	Inches		Inches			Percent	
20.91	36.97	176.6	0.03	0.1	+176	70	$AC'_2rc'_2$
19.19	32.17	167.1	0.06	0.3	+167	72	$AC'_2rc'_2$
9.88	--	--	11.54	53.9	- 32	69	$DC'_2dc'_2$
14.94	1.01	6.1	1.60	9.7	+ 0.3	77	$C_2C'_1dc'_1$
12.97	--	--	2.05	13.6	- 8	80	$C_1C'_2dc'_1$
16.80	18.92	110.3	0.35	2.0	+109	76	$AC'_2rc'_2$
15.04	64.97	430.8	0.04	0.3	+431	79	$AC'_1rc'_1$
13.31	--	--	3.66	21.6	- 13	76	$C_1C'_2dc'_2$
15.28	--	--	3.21	17.4	- 10.4	74	$C_1C'_2dc'_2$
19.37	16.19	83.1	0.12	0.6	+ 83	72	$B_4C'_2rc'_2$
8.82	--	--	2.52	22.2	- 13	88	$C_1C'_1dc'_1$
15.20	--	--	4.05	21.0	- 13	72	$C_1C'_2dc'_2$
20.51	18.00	85.3	0.59	2.8	+ 84	72	$B_4C'_2rc'_2$
15.28	3.41	19.9	1.89	11.0	+ 13	76	$C_2C'_2rc'_2$
23.70	72.89	307.6	0	0	+308	66	$AB'_1rb'_1$
20.91	88.20	421.8	0	0	+422	70	$AC'_2rc'_2$
20.55	39.09	190.2	0	0	+190	71	$AC'_2rc'_2$
8.31	--	--	4.60	35.6	- 21	84	$DC'_1dc'_1$
18.96	52.21	275.4	0	0	+275	73	$AC'_2rc'_2$
17.79	40.54	227.9	0	0	+228	75	$AC'_2rc'_2$
20.98	130.70	623.0	0	0	+623	70	$AC'_2rc'_2$
4.36	--	--	2.65	37.8	- 23	102	$DD'dd'$
6.28	--	--	1.16	15.6	- 9	100	$C_1D'dd'$
13.83	8.27	47.3	3.64	20.8	+ 45	75	$B_2C'_2sc'_2$
22.83	130.90	573.4	0	0	+573	68	$AB'_1rc'_2$
22.24	86.43	388.6	0	0	+389	68	$AC'_2rc'_2$
15.05	4.76	28.8	1.49	9.0	+ 23	77	$B_1C'_1rc'_1$
14.05	1.36	8.1	2.76	16.4	- 2	77	$C_1C'_1dc'_1$
13.11	--	--	3.74	22.2	- 13	76	$C_1C'_2dc'_2$
11.54	--	--	6.61	36.4	- 22	74	$DC'_2dc'_2$
15.07	2.84	15.7	2.99	16.6	+ 6.0	74	$C_2C'_2rc'_2$
6.21	16.06	252.9	0.14	2.2	+251	104	$AD'rd'$
13.23	--	--	3.07	18.9	- 11	77	$C_1C'_1dc'_1$
10.89	--	--	5.80	34.8	- 21	78	$DC'_1dc'_1$
15.78	3.89	22.5	1.51	8.7	+ 17	77	$C_2C'_2rc'_1$
22.17	90.06	405.7	0.03	0.1	+405	68	$AC'_2rc'_2$
8.74	--	--	5.87	40.2	- 24	80	$DC'_1dc'_1$
10.54	--	--	4.99	32.1	- 19	79	$C_1C'_1dc'_1$
18.32	28.25	154.4	0	0	+154	76	$AC'_2rc'_2$
21.73	54.76	252.0	0	0	+252	69	$AC'_2rc'_2$
19.07	64.23	336.8	0	0	+337	73	$AC'_2rc'_2$
9.65	4.20	40.7	0.68	6.6	+ 37	90	$B_1D'rd'$
14.50	28.11	193.9	0	0	+194	83	$AC'_1rc'_1$
14.29	12.34	83.4	0.51	3.4	+ 81	80	$B_4C'_1rc'_1$

Table 1.--*Location and climatic description for*

Station name[1]	Elevation	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapotranspiration (PET)
	Feet			Degrees F.	Inches	Inches
Cape Sarichef*[3]	175	54°33'	164°56'	38.0	74.25	18.07
Cape Spencer*	81	58°12'	136°38'	42.2	68.77	21.85
Cape St. Elias*	50	59°48'	144°36'	43.2	68.35	22.17
Cape Thompson*	33	68°06'	165°46'	18.9	14.21	11.85
Carmacks*	1,710	62°06'	136°18'	25.2	8.73	17.91
Caswell*	290	61°58'	150°01'	31.0	25.06	18.66
Central*	870	65°32'	144°48'	20.0	10.34	18.54
Chalkyitsik	560	66°38'	143°43'	17.0	5.30	15.55
Chena Hot Springs	1,574	65°03'	146°04'	20.9	11.14	15.89
Chernofski Harbor*	25	53°26'	167°21'	40.2	52.75	20.16
Chichagof*	10	57°40'	136°05'	41.9	122.91	21.38
Chickaloon*	929	61°48'	148°27'	32.7	14.00	18.11
Chicken	1,360	64°04'	141°56'	19.3	8.62	17.01
Chignik	10	56°18'	158°23'	37.0	158.1	16.63
Chistochina	2,000	62°34'	144°45'	26.2	12.4	18.85
Chitina*	580	61°32'	144°27'	28.3	12.81	18.39
Circle City	700	65°48'	144°04'	21.2	10.3	17.23
Circle Hot Springs*	1,000	65°29'	144°34'	22.2	10.20	17.80
Clear Airport	546	64°18'	149°09'	21.1	13.91	17.38
Clear Water	1,100	64°03'	145°31'	15.9	14.43	17.69
Coal Harbor*	30	55°24'	160°49'	39.1	48.51	18.82
Cold Bay*	93	55°12'	162°43'	38.4	33.20	17.81
Colleen River	1,120	67°45'	142°34'	14.7	11.15	13.19
Cooper Lake Project	350	60°22'	149°40'	37.3	30.79	19.14
Copper Center*	1,031	61°58'	145°19'	26.1	9.15	17.40
Copper Valley School	1,030	62°05'	145°18'	26.8	10.53	18.31
Cordova*	25	60°32'	145°45'	38.6	98.64	19.13
Council*	95	64°53'	163°41'	26.5	13.96	15.47
Craig*	13	55°29'	133°09'	44.9	106.26	23.46
Crooked Creek*	125	61°52'	158°15'	29.0	14.09	17.60
Curry*	516	62°37'	150°02'	34.9	43.67	18.94
Dahl	250	65°22'	164°41'	17.4	6.86	13.43
Davis River	22	55°46'	130°11'	39.9	100.6	19.40
Dawson*	1,062	64°04'	139°26'	23.6	12.67	18.11
Dease Lake*	2,678	58°25'	130°00'	19.6	15.25	10.20
Devil's Club	360	60°58'	149°11'	37.8	39.82	19.65
Dillingham*	50	59°03'	158°27'	33.4	25.03	17.95
Dutch Harbor*	13	53°53'	166°32'	40.7	61.64	20.59
Eagle*	821	64°45'	141°12'	25.1	11.24	17.67
Eielson Field*	547	64°39'	147°04'	25.1	13.99	18.39
Eklutna Lake*	882	61°24'	149°09'	30.7	12.38	16.93
Eklutna Project*	38	61°28'	149°10'	33.7	18.34	19.25
Eldred Rock*	55	58°58'	135°13'	41.9	51.21	21.50
Elmendorf*	192	61°14'	149°52'	34.8	15.73	19.65

NOTE: See footnotes at end of table.

315 stations in Alaska and adjacent Canada--Continued

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\,(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type[2/]
Inches	Inches		Inches			Percent	
17.83	56.18	310.9	0.24	1.3	+310	74	$AC'_2rc'_2$
21.85	46.92	214.7	0	0	+215	69	$AC'_2rc'_2$
22.17	46.18	208.3	0	0	+208	68	$AC'_2rc'_2$
10.67	2.36	19.9	1.18	10.0	+ 14	86	$C_2C'_1rc'_1$
8.62	--	--	9.29	51.9	- 31	75	$DC'_2dc'_2$
16.57	6.40	34.3	2.09	11.2	+ 27	73	$B_1C'_2rc'_2$
10.20	--	--	8.34	45.0	- 27	74	$DC'_2dc'_2$
5.30	--	--	10.25	65.9	- 39.5	79	$DC'_1dc'_1$
11.14	--	--	4.75	29.9	- 18	78	$DC'_1dc'_1$
20.04	32.59	161.7	0.12	0.6	+161	71	$AC'_2rc'_2$
21.38	101.53	474.9	0	0	+475	69	$AC'_2rc'_2$
12.68	--	--	5.43	30.0	- 18	74	$C_1C'_2dc'_2$
8.62	--	--	8.39	49.3	- 30	76	$DC'_2dc'_2$
16.63	141.47	850.7	0	0	+851	77	$AC'_1rc'_1$
12.30	--	--	6.55	34.7	- 21	73	$DC'_2dc'_2$
11.81	--	--	6.58	35.8	- 21	74	$DC'_2dc'_2$
10.15	--	--	7.08	41.1	- 25	76	$DC'_2dc'_2$
10.20	--	--	7.60	42.7	- 26	75	$DC'_2dc'_2$
12.37	--	--	5.01	28.8	- 17	75	$C_1C'_2dc'_2$
14.43	--	--	3.26	18.4	- 11	75	$C_1C'_2dc'_2$
18.80	29.69	157.8	0.02	0.1	+158	73	$AC'_2rc'_2$
17.52	15.39	86.4	0.29	1.6	+ 85	75	$B_4C'_2rc'_2$
11.15	--	--	2.04	15.5	- 6	83	$C_1C'_1dc'_1$
15.71	11.65	60.9	3.43	17.9	+ 51	73	$B_2C'_2rc'_2$
9.15	--	--	8.25	47.4	- 28	75	$DC'_2dc'_2$
10.53	--	--	7.78	42.5	- 26	74	$DC'_2dc'_2$
19.13	79.51	415.6	0	0	+416	73	$AC'_2rc'_2$
11.69	--	--	3.78	24.4	- 15	79	$C_1C'_1dc'_1$
23.46	82.80	352.9	0	0	+353	67	$AB'_1rb'_1$
14.09	--	--	3.51	19.9	- 12	75	$C_1C'_2dc_2$
18.62	24.73	130.6	0.32	1.7	+130	73	$AC'_2rc'_2$
6.86	--	--	6.57	48.9	- 29	83	$DC'_1dc'_1$
19.40	81.20	418.6	0	0	+419	72	$AC'_2rc'_2$
12.48	--	--	5.63	31.1	- 19	74	$C_1C'_2dc'_2$
9.65	5.05	49.5	0.55	5.4	+ 46	91	$B_2D'rd'$
18.34	20.17	102.6	1.31	6.7	+ 98	72	$B_4C'_2rc'_2$
16.53	7.08	39.4	1.42	7.9	+ 35	74	$B_1C'_2rc'_2$
19.92	41.05	199.4	0.67	3.3	+197	71	$AC'_2rc'_2$
10.41	--	--	7.26	41.1	- 25	75	$DC'_2dc'_2$
13.99	--	--	4.40	23.9	- 14	74	$C_1C'_2dc'_2$
12.32	--	--	4.61	27.2	- 16	76	$C_1C'_1dc'_2$
15.16	--	--	4.09	21.2	- 13	72	$C_1C'_2dc'_2$
20.47	29.71	138.2	1.03	4.8	+135	69	$AC'_2rc'_2$
15.31	--	--	4.34	22.1	- 13	72	$C_1C'_2dc'_2$

Table 1.--*Location and climatic description for*

Station name[1]	Eleva-tion	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapo-transpiration (PET)
	Feet			Degrees F.	Inches	Inches
Eureka	3,326	61°57'	147°10'	24.0	17.09	12.33
Fairbanks*[3]	436	64°49'	147°52'	26.2	11.92	18.35
False Pass	20	54°50'	163°40'	39.6	80.7	17.58
Farewell*	20	62°30'	153°54'	25.7	16.25	16.42
Five Finger Light*	70	57°16'	133°37'	43.4	57.84	22.48
Flat*	326	62°29'	158°05'	27.5	18.23	17.32
Fort Egbert	573	64°46'	141°12'	21.3	10.3	16.95
Fort Gibbon	235	65°12'	152°00'	23.3	10.7	16.91
Fort Liscom*	9	61°06'	146°27'	25.1	74.4	18.15
Fort Tongass*	20	54°45'	130°35'	47.8	133.8	24.92
Fort Yukon*	419	66°35'	145°18'	20.7	6.53	17.91
Fortmann*	132	55°36'	131°25'	45.2	144.40	21.93
Galena*	120	64°43'	156°54'	25.2	14.62	17.83
Gambell*	25	63°46'	171°48'	24.2	15.83	11.30
Geese Islands	15	56°43'	153°55'	41.9	57.4	21.76
Girdwood	50	60°56'	149°10'	35.9	38.4	19.27
Glennallen	1,456	62°07'	145°32'	22.9	8.21	15.57
Golovin	12	64°33'	163°01'	26.6	9.02	14.97
Goodnews Bay	20	59°10'	162°30'	31.4	25.3	15.60
Guard Island*	20	55°27'	131°53'	46.0	65.43	23.90
Gulkana*	1,572	62°17'	145°27'	26.9	11.70	17.44
Gull Cove*	18	58°12'	136°09'	41.6	102.84	21.02
Gustavus*	22	58°25'	135°42'	40.9	54.86	20.87
Haines*	100	59°14'	135°26'	40.3	60.64	20.79
Haines Junction*	1,960	60°46'	137°35'	26.5	10.94	16.57
Herschel Island*	15	69°35'	139°15'	10.7	5.91	9.06
High Lake Lodge	2,760	62°54'	149°05'	27.1	24.5	14.18
Hollis*	15	55°28'	132°40'	44.2	103.58	22.83
Holy Cross*	150	62°10'	159°45'	29.2	18.35	17.40
Homer*	67	59°38'	151°30'	37.3	25.25	18.86
Hooper Bay	35	61°32'	166°05'	30.0	17.07	15.24
Hughes*	545	66°04'	154°20'	23.6	13.91	17.56
Hyder*	9	55°55'	130°01'	40.9	89.58	21.30
Igloo	4	65°12'	165°04'	21.8	9.06	13.85
Iliamna*	145	59°44'	154°57'	33.7	25.78	17.80
Indian River	735	62°45'	149°50'	31.1	36.7	16.97
Iniskin*	300	59°45'	153°14'	33.9	78.23	17.36
Intricate Bay	170	59°43'	154°28'	33.7	35.05	16.62
Jualin	710	58°49'	135°02'	42.8	81.96	21.28
Juneau*	72	58°18'	134°24'	42.5	90.25	21.89
Juneau Airport*	12	58°22'	134°35'	40.5	54.62	20.63
Kake*	8	56°59'	133°55'	42.7	54.51	21.89
Kalsin Bay	20	57°34'	152°27'	39.7	100.3	17.91
Kalskag	90	61°27'	160°49'	28.6	12.8	18.07

NOTE: See footnotes at end of table.

315 stations in Alaska and adjacent Canada--Continued

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\ (P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type[2]
Inches	Inches		Inches			Percent	
12.18	4.76	38.6	0.15	1.2	+ 38	85	$B_1C'_1rc'_1$
10.94	--	--	7.41	40.4	- 24	74	$DC'_2dc'_2$
17.58	63.12	359.0	0	0	+359	75	$AC'_2rc'_2$
15.68	--	--	0.74	4.5	- 3	77	$C_1C'_1dc'_1$
22.28	35.36	157.3	0	0	+157	68	$AC'_2rc'_2$
13.81	0.91	5.3	3.51	20.3	- 7	75	$C_1C'_2dc'_2$
10.32	--	--	6.63	39.1	- 23	76	$DC'_2dc'_2$
10.70	--	--	6.21	36.7	- 22	76	$DC'_2dc'_2$
17.91	56.25	309.9	0.24	1.3	+309	74	$AC'_2rc'_2$
24.92	108.88	436.9	0	0	+437	65	$AB'_1rb'_1$
6.53	--	--	11.38	63.5	- 38	75	$DC'_2dc'_2$
21.93	122.47	558.5	0	0	+559	69	$AC'_2rc'_2$
14.62	--	--	3.21	18.0	- 11	75	$C_1C'_2dc'_2$
10.36	4.53	40.1	0.94	8.3	+ 35	88	$B_1C'_1rd'$
21.76	35.64	163.8	0	0	+164	69	$AC'_2rc'_2$
16.63	19.13	99.3	2.64	13.7	+ 91	72	$B_4C'_2rc'_2$
8.21	--	--	7.36	47.3	- 28	79	$DC'_1dc'_1$
9.02	--	--	5.95	39.7	- 24	80	$DC'_1dc'_1$
14.17	9.70	62.2	1.43	9.2	+ 57	78	$B_2C'_1rc'_1$
23.90	41.53	173.8	0	0	+174	66	$AB'_1rb'_1$
11.54	--	--	5.90	33.8	- 20.3	75	$DC'_2dc'_2$
21.00	81.82	389.2	0.02	0.1	+389	70	$AC'_2rc'_2$
20.67	33.99	162.9	0.20	1.0	+163	70	$AC'_2rc'_2$
18.58	39.85	191.7	2.21	10.6	+185	70	$AC'_2rc'_2$
10.94	--	--	5.63	34.0	- 20.4	77	$DC'_1dc'_1$
5.83	--	--	3.23	35.7	- 21	94	$DD'dd'$
13.92	10.32	72.8	0.26	1.8	+ 71	81	$B_3C'_1rc'_1$
22.71	80.75	353.7	0.12	0.5	+353	68	$AB'_1rc'_2$
14.64	0.95	5.5	2.76	15.9	- 4	75	$C_1C'_2dc'_2$
16.65	6.39	33.9	2.21	11.7	+ 27	73	$B_1C'_2rc'_2$
13.91	1.83	12.0	1.33	8.7	+ 7	79	$C_2C'_1rc'_1$
13.43	--	--	4.13	23.5	- 14	75	$C_1C'_2dc'_2$
21.06	68.28	320.6	0.24	1.12	+320	70	$AC'_2rc'_2$
8.80	--	--	5.05	36.5	- 22	82	$DC'_1dc'_1$
16.38	7.98	44.8	1.42	8.0	+ 40	75	$B_2C'_2rc'_2$
14.88	19.73	116.3	2.09	12.3	+109	76	$AC'_2rc'_2$
17.36	60.87	350.6	0	0	+351	75	$AC'_2rc'_2$
16.30	18.43	110.9	0.32	1.9	+109.8	77	$AC'_1rc'_1$
21.05	60.68	285.2	0.23	1.1	+284	70	$AC'_2rc'_2$
21.89	68.36	312.2	0	0	+312	69	$AC'_2rc'_2$
20.53	33.99	164.8	0.10	0.5	+165	70	$AC'_2rc'_2$
21.38	32.62	149.0	0.51	2.4	+148	69	$AC'_2rc'_2$
17.91	82.39	460.0	0	0	+460	75	$AC'_2rc'_2$
12.80	--	--	5.27	29.2	- 18	74	$C_1C'_2dc'_2$

Table 1.--*Location and climatic description for*

Station name[1]	Eleva-tion	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapo-transpiration (PET)
	Feet			Degrees F.	Inches	Inches
Kanatak	23	57°34'	156°02'	42.1	57.83	20.84
Kasilof*[3]	80	60°23'	151°17'	34.8	17.10	18.82
Katalla	10	60°12'	144°33'	41.3	110.6	19.05
Kenai*	85	60°34'	151°16'	33.3	18.42	17.17
Kennecott*	2,210	61°29'	142°53'	30.2	23.47	16.57
Kenney Lake	1,200	61°44'	144°43'	26.6	16.95	15.07
Kensington Mine	2,025	58°52'	135°08'	40.0	74.65	19.40
Kechumstuk	2,600	64°07'	142°20'	18.1	13.4	14.22
Ketchikan*	15	55°21	131°39'	46.1	151.19	23.74
Killisnoo*	20	57°22'	134°29'	40.7	52.9	20.67
Kinsham Cove	13	57°41'	136°06'	44.8	117.0	22.14
King Island	100	64°56'	168°01'	29.2	12.53	14.08
King Salmon*	44	58°41'	157°05'	34.1	22.46	17.87
Kitimat*	55	54°00'	128°42'	37.8	96.78	18.90
Kitoi Bay*	20	58°11'	152°21'	39.1	62.62	16.57
Kiukpalik Island	20	58°36'	153°34'	38.8	75.7	17.47
Klatt's Farm	150	61°04'	149°54'	33.8	16.53	18.96
Klukwan*	91	59°24'	135°54	35.7	21.16	19.80
Kobuk	140	66°54'	156°52'	19.4	20.7	14.30
Kodiak*	152	57°48'	152°24'	40.5	61.54	19.96
Kokhanok Bay*	115	59°30'	154°52'	33.0	31.33	16.18
Komakuk Beach	30	69°35'	140°11'	10.9	6.06	9.80
Kotzebue*	10	66°52'	162°38'	20.6	8.02	13.39
Ladd Air Force Base*	464	64°50'	147°36'	26.7	12.60	18.70
Lake Chandalar	1,900	67°30'	148°30'	14.2	12.01	13.25
Lake Minchumina*	693	63°53'	152°17'	25.3	11.99	17.87
Lake Nerka*	65	59°34'	159°02'	31.1	57.85	17.44
Larsen Bay*	15	57°32'	154°05'	39.4	21.90	20.27
Latouche*	45	60°03'	147°54'	41.5	180.96	20.67
Lazy Bay	12	56°53'	154°15'	40.3	45.41	19.31
Lignite	1,176	63°57'	148°59'	27.0	16.0	15.85
Lincoln Rock*	25	56°03'	132°46'	44.9	60.31	23.39
Linger Longer	700	59°26'	136°17'	37.7	36.63	19.10
Little Diomede	150	65°45'	168°56'	22.1	28.71	10.60
Little Port Walter*	14	56°23'	134°39'	43.2	222.47	22.32
Livengood*	730	65°30'	148°29'	24.8	12.75	17.95
Mankomen Lake	3,330	62°59'	144°29'	24.3	26.0	14.59
Manley Hot Springs*	265	65°00'	150°39'	25.1	15.19	17.80
Matanuska Expt. Station*	150	61°34'	149°16'	35.5	15.40	19.76
May Creek	1,500	62°21'	142°41'	26.1	13.90	15.01
Mayo Landing*	1,625	63°36'	135°53'	14.3	11.16	11.89
McGrath*	334	62°58'	155°37'	25.2	19.13	17.68
McKinley Park*	2,092	63°42'	149°00'	27.5	14.44	14.61
Meier	2,717	62°47'	145°27'	22.4	15.27	13.35

NOTE: See footnotes at end of table.

315 stations in Alaska and adjacent Canada--Continued

Actual evapo- transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type[2/]
Inches	Inches		Inches			Percent	
20.78	36.99	177.5	0.06	0.3	+177	70	$AC'_2rc'_2$
15.24	--	--	3.58	19.0	- 11	73	$C_1C'_2dc'_2$
19.05	91.55	480.6	0	0	+481	73	$AC'_2rc'_2$
15.12	1.25	7.3	2.05	11.9	+ 0.2	76	$C_2C'_2rc'_2$
15.00	6.90	41.6	1.57	9.5	+ 36	77	$B_1C'_1rc'_1$
10.78	1.88	12.5	4.29	28.5	- 4.6	79	$C_1C'_1dc_1$
19.14	55.25	284.8	0.26	1.3	+284	72	$AC'_2rc'_2$
11.75	--	--	2.47	17.4	- 10.4	81	$C_1C'_1dc'_1$
23.74	127.45	536.9	0	0	+537	66	$AB'_1rb'_1$
20.31	32.23	155.9	0.36	1.74	+155	70	$AC'_2rc'_2$
22.14	94.86	428.5	0	0	+429	68	$AC'_2rc'_2$
10.45	--	--	3.63	25.8	- 15	81	$C_1C'_1dc'_1$
15.98	4.59	25.7	1.89	10.6	+ 19	75	$C_2C'_2rc'_2$
18.90	77.88	412.1	0	0	+412	73	$AC'_2rc'_2$
16.57	45.05	271.9	0	0	+272	77	$AC'_1rc'_1$
17.47	58.23	333.3	0	0	+333	75	$AC'_2rc'_2$
15.45	--	--	3.51	18.5	- 11	73	$C_1C'_2dc'_2$
15.17	1.36	6.9	4.63	23.4	- 7	72	$C_1C'_2dc'_2$
12.13	6.40	44.8	2.17	15.2	+ 36	81	$B_1C'_1rc'_1$
19.92	41.58	209.3	0.04	0.2	+209	71	$AC'_2rc'_2$
15.57	15.15	93.6	0.61	3.8	+ 91	77	$B_4C'_1rc'_1$
5.90	--	--	3.90	39.8	- 24	92	$DD'dd'$
8.02	--	--	5.37	40.1	- 24	83	$DC'_1dc'_1$
12.60	--	--	6.10	32.6	- 19.6	72	$C_1C'_2dc'_2$
10.73	--	--	2.52	19.0	- 11	83	$C_1C'_1dc'_1$
11.99	--	--	5.88	32.9	- 19.7	75	$C_1C'_2dc'_2$
17.44	40.41	231.7	0	0	+232	75	$AC'_2rc'_2$
16.18	1.63	8.0	4.09	20.2	- 4	71	$C_1C'_2dc'_2$
20.67	160.29	775.5	0	0	+776	70	$AC'_2rc'_2$
19.04	26.10	135.2	.27	1.4	+134	72	$AC'_2rc'_2$
14.29	0.15	1.0	1.56	9.8	- 4.9	78	$C_1C'_1dc'_1$
23.36	36.92	157.8	0.03	0.1	+158	67	$AB'_1rc'_2$
14.99	17.53	91.8	4.11	21.5	+ 79	73	$B_3C'_2sc'_2$
9.41	18.11	170.8	1.19	11.2	+164	90	$AD'rd'$
22.32	200.15	896.7	0	0	+897	68	$AC'_2rc'_2$
12.72	--	--	5.23	29.1	- 17	74	$C_1C'_1dc'_2$
14.57	11.41	78.2	0.02	0.1	+ 78	80	$B_3C'_1rc'_1$
14.80	--	--	3.00	16.9	- 10.1	75	$C_1C'_1dc'_2$
15.40	--	--	4.36	22.1	- 13	72	$C_1C'_2dc'_2$
11.86	--	--	3.15	21.0	- 13	80	$C_1C'_1dc'_1$
9.09	--	--	2.80	23.5	- 14	86	$C_1D'dc'_1$
15.54	1.45	8.2	2.14	12.1	+ 1	75	$C_2C'_1rc'_2$
13.58	--	--	3.03	18.2	- 11	77	$C_1C'_1dc'_1$
12.83	1.92	14.4	0.52	3.9	+ 10.4	83	$C_2C'_1rc'_1$

Table 1.--*Location and climatic description for*

Station name[1]	Eleva- tion	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapo- transpiration (PET)
	Feet			Degrees F.	Inches	Inches
Mendenhall* [3]	85	58°24'	134°32'	40.0	93.73	20.71
Middleton Island*	39	59°28'	146°19'	42.1	61.01	21.93
Mile 28, Haines H'way	400	50°24'	135°54'	35.5	31.79	19.76
Moose Pass	480	60°28'	149°23'	33.5	43.66	17.39
Moose Run	395	61°15'	149°40'	33.0	19.2	17.43
Moose Valley*	400	59°25'	136°03'	35.8	33.15	19.65
Moses Point*	15	64°43'	162°04'	25.0	20.50	15.71
Mountain Village*	39	62°07'	163°45'	27.7	16.26	16.18
Naknek*	49	58°45'	157°05'	34.4	22.89	18.66
Nenana*	356	64°33'	149°05'	25.8	11.13	18.11
New Hazelton*	1,150	55°14'	127°36'	29.3	19.17	14.06
Nikolski	18	52°27'	168°52'	38.0	32.81	16.62
Ninilchik	25	60°05	151°40'	34.3	25.54	16.33
Nome*	13	64°30'	165°26'	26.3	18.96	15.00
Noorvik*	68	66°50'	161°00'	22.1	16.40	12.01
North Dutch Island*	33	60°46'	147°48'	41.0	126.84	20.20
Northeast Cape*	38	63°17'	168°41'	25.1	18.24	12.05
North Fork	2,700	64°30'	142°10'	19.9	12.6	16.00
Northway*	1,713	63°00'	141°50'	22.4	11.34	17.52
Nulato*	210	64°43'	158°04'	25.9	15.60	16.26
Nunivak*	40	60°23'	166°12'	29.6	14.65	15.28
Nyac*	450	61°00'	159°59'	30.4	22.65	17.01
Ohogamiut	45	61°38'	161°54'	33.3	23.65	21.54
Old Crow*	800	67°35'	139°50'	13.3	7.54	13.74
Ophir	400	63°10'	156°33'	19.9	12.6	16.00
Palmer*	220	61°37'	149°06'	35.6	16.61	19.72
Passage Canal	12	60°47'	148°13'	39.8	190.19	19.18
Paxson*	2,697	63°03'	145°27'	24.3	19.65	14.53
Perseverence Camp	1,100	58°18'	134°20'	37.7	160.1	18.85
Petersburg*	50	56°49'	132°57'	42.3	105.01	21.69
Pilgrim Springs*	50	65°05'	164°58'	24.1	5.86	15.71
Pilot Point	50	57°37'	157°34'	37.4	19.8	18.25
Pilot Station*	50	61°58'	163°00'	28.4	16.61	16.18
Platinum*	20	59°01'	161°47'	32.2	18.75	16.93
Point Hope*	13	68°20'	166°48'	18.7	10.21	10.87
Point Lay*	10	69°45'	163°03'	13.3	6.91	10.75
Point Retreat*	20	58°25'	134°57'	42.2	78.68	21.38
Porcupine Creek*	1,800	59°22'	136°16'	34.5	39.00	19.13
Port Alexander*	18	56°10'	134°45'	43.8	169.10	22.80
Port Alsworth	230	60°12'	154°18'	32.8	21.32	16.72
Port Heiden	92	56°57'	158°37'	36.1	17.11	16.76
Port Moller*	18	55°56'	160°30'	38.1	19.2	18.94
Portage*	35	60°51'	148°59'	36.5	57.13	19.29
Prince Rupert*	170	54°17'	130°23'	40.0	94.41	20.24

NOTE: See footnotes at end of table.

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\ (P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type[2]
Inches	Inches		Inches			Percent	
20.71	73.02	352.6	0	0	+353	70	$AC'_2rc'_2$
21.77	39.08	178.2	0.16	0.7	+178	69	$AC'_2rc'_2$
15.39	12.03	60.9	4.37	22.1	+ 48	72	$B_2C'_2sc'_2$
13.63	26.27	151.1	3.76	21.6	+138	75	$AC'_2rc'_2$
14.00	1.77	10.2	3.43	19.67	- 2	75	$C_1C'_2sc'_2$
15.79	13.50	68.7	3.86	19.64	+ 57	72	$B_2C'_2sc'_2$
14.50	4.79	30.5	1.21	7.7	+ 25	78	$B_1C'_1sc'_1$
13.67	.08	0.5	2.51	15.5	- 9	77	$C_1C'_1dc'_1$
17.48	4.23	22.7	1.18	6.3	+ 19	73	$C_2C'_2rc'_2$
11.02	--	--	7.09	39.1	- 23	74	$DC'_2dc'_2$
12.96	5.11	36.3	1.10	7.8	+ 32	81	$B_1C'_1rc'_1$
16.47	16.19	97.4	0.15	0.9	+ 97	77	$B_1C'_1rc'_1$
14.42	9.21	56.4	1.91	11.7	+ 49	77	$B_2C'_1rc'_1$
14.13	3.96	26.4	0.87	5.80	+ 23	80	$B_1C'_1rc'_1$
10.69	4.39	36.6	1.32	11.0	+ 30.0	86	$B_1C'_1rc'_1$
20.20	106.64	527.9	0	0	+528	71	$AC'_2rc'_2$
10.59	6.19	51.4	1.46	12.1	+ 44	85	$B_2C'_1rc'_1$
12.55	--	--	3.45	21.6	- 13	78	$C_1C'_1dc'_1$
11.34	--	--	6.18	35.3	- 21	75	$DC'_2dc'_2$
12.09	--	--	4.17	25.6	- 15	77	$C_1C'_1dc'_1$
13.08	--	--	2.20	14.4	- 9	79	$C_1C'_1dc'_1$
15.57	5.64	33.2	1.44	8.5	+ 28	76	$B_1C'_1rc'_2$
18.45	2.11	9.8	3.09	14.3	+ 1	69	$C_2C'_2rc'_2$
7.52	--	--	6.22	45.3	- 27	82	$DC'_1dc'_1$
12.60	--	--	3.40	21.25	- 13	76	$C_1C'_1dc'_2$
16.61	--	--	3.11	15.8	- 9.5	72	$C_1C'_2dc'_2$
19.18	171.01	891.6	0	0	+892	73	$AC'_2rc'_2$
13.72	5.12	35.2	0.81	5.6	+ 32	81	$B_1C'_2rc'_1$
18.85	141.25	749.3	0	0	+749	73	$AC'_1rc'_2$
21.69	83.32	383.7	0	0	+384	69	$AC'_2rc'_2$
5.86	--	--	9.85	62.7	- 37.6	78	$DC'_1dc'_1$
16.13	1.55	8.5	2.12	11.6	+ 1.5	74	$C_2C'_2rc'_2$
14.29	0.43	2.7	1.89	11.7	- 4	77	$C_1C'_1dc'_1$
14.54	1.82	10.8	2.39	14.1	+ 2	76	$C2C'_2rc'_2$
7.56	--	--	3.31	30.5	- 18	89	$C_1D'dd'$
6.91	--	--	3.84	35.7	- 21	89	$DD'dd'$
21.34	57.30	268.0	0.04	0.2	+268	69	$AC'_2rc'_2$
16.42	19.87	103.9	2.71	14.2	+ 95	73	$B_4C'_2rc'_2$
22.80	146.30	641.7	0	0	+642	68	$AB'_1rc'_2$
15.45	4.60	27.5	1.27	7.6	+ 23	76	$B_1C'_1rc'_2$
15.36	0.35	2.1	1.40	8.4	- 3	76	$C_1C'_1dc'_2$
15.04	0.26	1.4	3.90	20.6	- 11	73	$C_1C'_2dc'_2$
18.82	37.84	196.2	0.47	2.4	+195	72	$AC'_2rc'_2$
20.24	74.17	366.5	0	0	+367	71	$AC'_2rc'_2$

Table 1.--*Location and climatic description for*

Station name[1]	Elevation	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapotranspiration (PET)
	Feet			Degrees F.	Inches	Inches
Puntilla*[3]	1,837	62°06'	152°45'	25.9	14.24	15.55
Radioville*	15	57°36'	136°09'	45.0	122.79	23.50
Rampart*	375	65°30'	150°15'	22.7	9.88	18.03
Rapids*	2,128	63°32'	145°51'	29.9	18.58	17.24
Richardson*	880	64°17'	146°22'	28.9	12.89	18.62
Ruby*	705	64°44'	155°26'	27.1	17.16	17.91
Salmon Creek Beach	20	58°19'	134°28'	40.9	106.8	20.09
Sand Point*	32	55°20'	160°30'	38.1	71.3	18.50
Savoonga*	35	63°41'	170°26'	23.5	9.95	11.50
Scotch Cap*	20	54°25'	164°45'	40.5	50.82	20.71
Seclusion Harbor*	20	56°33'	134°03'	43.1	111.9	22.17
Selawik	20	66°36'	160°02'	18.6	9.74	15.17
Seldovia	30	59°26'	151°43'	34.7	40.84	18.29
Seward*	76	60°07'	149°27'	39.4	68.98	19.88
Shaktolik	15	64°15'	161°09'	24.5	16.30	13.10
Shaw Island	8	58°12'	136°15'	43.3	105.0	21.81
Shearwater Bay*	5	57°21'	152°55'	40.2	96.84	19.76
Sheep Mountain*	2,280	61°48'	147°41'	28.8	11.01	16.42
Shemya*	92	57°42'	174°06'E.	38.8	26.15	18.70
Shingle Point*	120	68°57'	137°12'	13.1	7.32	12.44
Shishmaref*	16	66°14'	166°07'	20.5	8.00	12.40
Shungnak*	138	66°54'	157°02'	21.7	20.04	15.94
Sitka*	67	57°03'	135°20'	43.3	96.33	22.64
Sitkinak	53	56°33'	154°08'	39.9	53.4	18.09
Skagway*	18	59°27'	135°19'	41.1	29.86	20.87
Skwentna*	153	61°57'	151°10'	32.6	29.87	18.46
Slana	2,200	62°43'	143°55'	27.7	21.13	15.88
Sleetmute	285	61°42'	157°11'	25.9	23.44	15.46
Smeaton Bay	16	55°19'	130°47'	42.1	104.59	21.26
Smithers*	1,690	54°44'	127°06'	28.6	20.27	14.76
Snag*	1,925	62°22'	140°24'	21.4	14.07	17.20
Snowshoe Lake	2,500	62°02'	146°40'	21.5	11.6	12.58
Soldatna	85	60°29'	151°05'	31.8	19.1	16.97
Sparrevohn*	1,580	61°06'	155°34'	30.3	25.64	16.89
St. George Island*	100	56°36'	169°32'	36.3	29.27	16.61
St. Michael*	50	63°29'	162°01'	26.1	13.19	14.92
St. Paul Island*	22	57°09'	170°13'	35.2	24.24	15.94
Stampede	2,500	63°44'	150°22'	26.6	19.28	15.85
Sterling*	250	60°32'	150°45'	31.8	16.68	17.72
Stewart*	150	55°58'	129°58'	33.8	70.92	16.22
Stony River	221	61°46'	156°38'	28.3	22.03	16.98
Stuyahok	500	62°05'	161°00'	27.4	28.4	15.46
Sulzer	25	55°12'	132°49'	46.0	111.1	24.01
Summit*	2,401	63°20'	149°09'	25.8	22.25	15.51

NOTE: See footnotes at end of table.

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\,(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100\,(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6 Ia	Summer need	Climatic type[2/]
Inches	Inches		Inches			Percent	
13.55	--	--	1.97	12.7	- 7	79	$C_1C'_1dc'_1$
23.50	99.29	422.5	0	0	+423	67	$AB'_1r'_1$
9.88	--	--	8.15	45.2	- 27	74	$DC'_2dc'_2$
16.24	1.34	7.8	1.00	5.8	+ 4	76	$C_2C'_2rc'_2$
12.89	--	--	5.73	30.8	- 18	73	$C_1C'_2dc'_2$
13.78	--	--	4.13	23.1	- 14	75	$C_1C'_2dc'_2$
20.09	86.71	431.6	0	0	+432	71	$AC'_2rc'_2$
18.42	52.8	285.4	0.08	0.4	+285	74	$AC'_2rc'_2$
9.80	--	--	1.70	14.8	- 9	87	$C_1C'_1dc'_1$
20.71	30.11	145.4	0	0	+145	70	$AC'_2rc'_2$
22.17	89.73	404.07	0	0	+405	68	$AC'_2rc'_2$
9.74	--	--	5.43	35.8	- 21	79	$DC'_1dc'_1$
15.97	22.55	123.3	2.32	12.7	+114	74	$AC'_2rc'_2$
19.49	49.10	247.0	0.39	2.0	+246	71	$AC'_2rc'_2$
12.37	3.20	24.4	0.73	5.6	+ 21	84	$B_2C'_2rc'_2$
21.33	83.19	381.4	0.48	2.2	+380	69	$AC'_2rc'_2$
19.76	77.08	390.1	0	0	+390	72	$AC'_2rc'_2$
11.01	--	--	5.41	32.9	- 19.7	77	$C_1C'_1dc'_1$
17.76	7.45	39.8	0.94	5.02	+ 36	73	$B_1C'_2rc'_2$
7.32	--	--	5.12	41.2	- 25	85	$DC'_1dc'_1$
8.00	--	--	4.40	35.5	- 21	85	$DC'_1dc'_1$
15.45	4.10	25.7	0.49	3.1	+ 23	78	$B_1C'_1rc'_1$
22.64	73.69	325.5	0	0	+326	67	$AB'_1rb'_1$
17.97	35.31	195.2	0.12	0.7	+195	74	$AC'_2rc'_2$
16.57	8.99	43.1	4.30	20.6	+ 31	70	$B_1C'_2sc'_2$
16.97	11.41	61.8	1.49	8.1	+ 57	74	$B_2C'_2rc'_2$
15.16	5.25	33.1	0.72	4.5	+ 30.4	78	$B_1C'_1rc'_1$
14.49	7.98	51.6	0.97	6.3	+ 47	79	$B_2C'_1rc'_1$
21.23	83.33	392.0	0.03	0.1	+392	70	$AC'_2rc'_2$
13.32	5.51	37.3	1.44	9.8	+ 31	80	$B_1C'_1rc'_1$
14.07	--	--	3.13	18.2	- 11	75	$C_1C'_2dc'_2$
11.54	--	--	1.04	8.3	- 5	85	$C_1C'_1dc'_1$
14.31	2.13	12.6	2.66	15.7	+ 3	76	$C_2C'_2rc'_2$
16.44	8.75	51.8	0.45	2.7	+ 50	76	$B_2C'_2rc'_2$
16.34	12.66	76.2	0.27	1.6	+ 75	77	$B_3C'_1rc'_1$
11.81	--	--	3.11	20.8	- 12	80	$C_1C'_1dc'_1$
15.34	8.30	52.1	0.60	3.7	+ 50	78	$B_2C'_1rc'_1$
15.11	3.43	21.6	0.74	4.7	+ 19	78	$C_2C'_1rc'_1$
13.70	--	--	4.02	22.7	- 14	75	$C_1C'_2dc'_2$
16.10	54.70	337.2	0.12	0.73	+337	77	$AC'_1rc'_1$
15.44	5.05	29.7	1.54	9.1	+ 24	76	$B_1C'_2rc'_2$
14.56	12.94	83.7	0.90	5.8	+ 80.2	79	$B_4C'_1rc'_1$
24.01	87.09	362.7	0	0	+363	66	$AB'_1rb'_1$
15.09	6.74	43.5	0.42	2.7	+ 42	79	$B_2C'_1rc'_1$

Table 1.--*Location and climatic description for*

Station name1/	Elevation	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapotranspiration (PET)
	Feet			Degrees F.	Inches	Inches
Summit Nike Site	3,980	61°15'	149°33'	29.3	30.7	12.69
Sunrise*3/	50	60°55'	149°35'	33.8	35.4	17.87
Susitna*	40	61°30'	150°40'	36.0	28.6	19.76
Taku Pass*	175	58°33'	133°41'	39.0	60.3	20.83
Talkeetna*	345	62°18'	150°06'	33.2	28.85	18.70
Tanaga Island	145	51°45'	178°02'	39.1	44.67	18.91
Tanacross*	1,546	63°24'	143°19'	23.5	10.02	17.52
Tanalian Point*	308	60°13'	154°22'	35.2	21.66	18.94
Tanana*	232	65°10'	152°06'	23.9	13.03	17.52
Telegraph Creek*	550	57°54'	131°09'	25.9	12.59	14.33
Teller*	10	65°16'	166°21'	24.7	11.92	13.54
Tenakee	19	57°47'	135°12'	42.8	68.41	21.01
Terrace*	719	54°28'	128°35'	36.1	47.18	17.91
Thane	20	58°15'	134°21'	41.5	81.5	19.54
Thompson Pass*	2,700	61°07'	145°44'	28.3	88.66	13.11
Thornbrough*	99	55°12'	162°43'	37.5	33.10	18.07
Tiekel	2,500	61°20'	144°55'	27.6	21.2	17.37
Tok	1,632	63°20'	143°02'	23.3	12.24	16.74
Tonsina	1,500	61°38'	145°11'	26.6	12.97	15.79
Tree Point*	36	54°48'	130°56'	45.8	96.67	23.94
Trims Camp*	2,408	63°26'	145°46'	26.5	36.11	17.29
Tunnel	500	60°41'	149°02'	37.3	44.67	17.94
Tyonek*	50	61°05'	151°15'	35.3	23.2	19.57
Uganik Bay*	50	57°43'	153°19'	40.7	42.06	20.24
Umiat*	337	69°22'	152°08'	11.1	5.51	11.34
Umnak	130	53°23'	167°54'	29.3	38.8	19.77
Unalakleet*	14	63°54'	160°47'	26.7	13.66	16.10
Unalaska	15	53°52'	166°31'	40.5	60.97	19.05
University Experiment Station*	481	64°51'	147°52'	25.6	13.37	18.31
Unuk River	5	56°04'	131°06'	40.5	118.82	18.94
Valdez*	15	61°07'	146°16'	35.6	62.05	18.62
Venetie	620	67°00'	146°34'	17.8	9.85	17.00
Venta	150	59°50'	150°58'	37.6	24.41	19.00
View Cove*	13	55°04'	133°04'	46.3	161.87	24.09
Wainwright*	29	70°40'	160°00'	11.7	4.10	8.58
Wales*	9	65°37'	168°03'	21.0	10.54	11.65
Wasilla	400	61°35'	149°28'	35.0	17.21	17.79
Whale Island*	46	57°58'	152°46'	39.8	54.03	19.69
Whitehorse*	2,103	60°43'	135°04'	30.8	10.05	18.23
White Mountain	50	64°41'	163°24'	27.0	15.36	16.1[illegible]
Whittier*	31	60°47'	148°41'	39.0	163.74	19.57
Wild Lake	2,200	67°29'	151°36'	15.7	12.23	13.16
Willow	600	61°45'	150°00'	32.4	29.16	17.28
Windham	6	57°32'	133°29'	41.2	100.10	19.85

NOTE: See footnotes at end of table.

315 stations in Alaska and adjacent Canada--Continued

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\,(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6Ia	Summer need	Climatic type2/
Inches	Inches		Inches			Percent	
11.75	18.01	141.9	0.94	7.4	+138	84	$AC'_1rc'_1$
16.02	17.53	98.1	1.85	10.4	+ 92	75	$B_4C'_2rc'_2$
18.40	8.84	44.7	1.36	6.9	+ 41	72	$B_2C'_2rc'_2$
20.28	39.47	189.5	0.55	2.6	+188	70	$AC'_2rc'_2$
17.28	10.15	54.3	1.42	7.6	+ 50	73	$B_2C'_2rc'_2$
18.21	25.76	136.2	0.70	3.7	+134	73	$AC'_2rc'_2$
9.92	--	--	7.60	43.4	- 26	75	$DC'_2dc'_2$
14.71	2.72	14.4	4.23	22.3	+ 1	73	$C_2C'_2sc'_2$
13.03	--	--	4.49	25.6	- 15	75	$C_1C'_2dc'_2$
9.49	--	--	4.84	33.8	- 20.3	81	$DC'_1dc'_1$
9.76	--	--	3.78	27.9	- 17	83	$C_1C'_1dc'_1$
20.93	47.40	225.6	0.08	0.4	+225	70	$AC'_2rc'_2$
16.50	29.27	163.4	1.41	7.9	+159	75	$AC'_2rc'_2$
19.54	61.96	317.1	0	0	+317	72	$AC'_2rc'_2$
13.11	75.55	576.3	0	0	+576	84	$AC'_1rc'_1$
17.13	15.03	83.2	0.94	5.2	+ 80.1	74	$B_4C'_2rc'_2$
14.27	3.83	22.0	3.10	17.8	+ 11	75	$C_2C'_2sc'_2$
12.24	--	--	4.50	26.9	- 16	77	$C_1C'_2dc'_1$
10.19	--	--	5.60	35.5	- 21	78	$DC'_1dc'_1$
23.94	72.73	303.8	0	0	+304	66	$AB'_1rb'_1$
13.19	18.82	108.8	4.10	23.7	+106	81	$AC'_2sc'_1$
16.39	206.73	149.0	1.55	8.6	+144	74	$AC'_2rc'_2$
16.31	3.63	18.5	3.26	16.7	+ 8.5	72	$C_2C'_2sc'_2$
18.54	21.82	107.8	1.70	8.4	+103	71	$AC'_2rc'_2$
5.31	--	--	6.03	53.2	- 32	88	DC'_1dd'
19.69	19.03	96.3	0.08	0.4	+ 96	72	$B_4C'_2rc'_2$
12.91	--	--	3.19	19.8	- 12	78	$C_1C'_1dc'_1$
18.59	41.92	220.1	0.46	2.4	+219	73	$AC'_2rc'_2$
11.93	--	--	6.38	34.8	- 21	74	$DC'_2dc'_2$
18.70	99.88	527.3	0.24	1.3	+526	73	$AC'_2rc'_2$
18.50	43.43	233.2	0.12	0.6	+233	73	$AC'_2rc'_2$
9.85	--	--	7.15	42.1	- 25	76	$DC'_2dc'_2$
15.50	5.41	28.5	3.50	18.4	+ 18	73	$C_2C'_2sc'_2$
24.09	137.78	571.9	0	0	+572	66	$AB'_1rb'_1$
4.10	--	--	4.48	52.2	- 31	96	$DD'dd'$
10.39	--	--	1.26	10.8	- 6	87	$C_1C'_1dc'_1$
15.48	--	--	2.31	13.0	- 8	75	$C_1C'_2dc'_2$
19.57	34.34	174.4	0.12	0.6	+174	72	$AC'_2rc'_2$
10.05	--	--	8.18	44.9	- 26.9	74	$DC'_2dc'_2$
12.13	--	--	3.97	24.7	- 15	78	$C_1C'_1dc'_1$
19.57	144.17	736.7	0	0	+737	72	$AC'_2rc'_2$
11.07	--	--	2.09	15.9	- 9.5	83	$C_1C'_1dc'_1$
14.43	11.88	68.8	2.85	16.5	+ 59	76	$B_2C'_2rc'_2$
19.85	80.25	404.3	0	0	+404	72	$AC'_2rc'_2$

Table 1.--*Location and climatic description for*

Station name[1]	Eleva-tion	Latitude (North)	Longitude (West)	Mean annual temperature	Mean annual precipitation (P)	Potential evapo-transpiration (PET)
	Feet			Degrees F.	Inches	Inches
Wiseman* [3]	1,286	67°26'	150°13'	22.0	15.36	16.57
Wonder Lake	2,000	63°28'	150°52'	31.8	19.50	18.48
Woody Island*	101	57°45'	152°20'	41.9	50.31	21.06
Wosnessenski	25	55°13'	161°21'	42.2	39.52	22.96
Wrangell*	37	56°28'	132°23'	43.7	82.90	22.60
Yakataga*	27	60°05'	142°30'	39.7	106.9	19.80
Yakutat*	28	59°31'	139°40'	39.3	134.15	19.80

1/ Spelling and location of station names are according to U.S. Geological Survey map E of Alaska, 1954.

2/ Thornthwaite's climatic type symbols.

3/ Asterisk denotes a climatic station for which complete water balance data are on file at the Institute of Northern Forestry, Juneau, Alaska.

A very cold climate (D D'dd'; i.e., semiarid, tundra, little or no water surplus, temperature efficiency normal to tundra) extends along most of the Arctic coast eastward from Point Lay. Here, mean annual temperature is about 10° F., precipitation only 5 or 6 inches per year, almost entirely snow. Climate near the tops of the high Rocky Mountains and temperatures on Mount Washington may approach this severity. In western Alaska, both temperature and precipitation decrease to the northward. Other generalizations are difficult, probably because continental, oceanic, and topographic influences on weather cause considerable variation among data from neighboring climatic stations.

Monthly PET at University Experiment Station, computed by three widely used estimating methods, is compared in figure 2. Annual PET by these methods agrees rather closely (Penman, 15.70 inches; evaporation pan, 18.68 inches; Thornthwaite, 17.87 inches). Papadakis (1961) estimated 15.75 inches PET at Fairbanks whereas Patric (1967) estimated 15.60 inches, using Hamon's (1964) equation. These annual figures are consistent with other comparisons which usually report annual values of PET by Thornthwaite's method higher than other estimates. Relative humidity strongly influenced Penman and evaporation pan estimates of monthly PET but could not influence Thornthwaite estimates which are based solely on temperature. Thus, figure 2 shows Thornthwaite estimates of PET low during the least humid months of May and June, highest during the more humid months of July, August, and September.

Figure 3 is a generalized map of PET for Alaska. The isolines of PET must be interpreted very carefully since the station values on which these lines are based were heavily biased to sea-level and valley-bottom climates. The climatic records for high-elevation stations are few, commonly of short

Actual evapo-transpiration (AET)	Surplus P-PET	Index of humidity $Ih = \frac{100\,(P-PET)}{PET}$	Deficit PET-AET	Index of aridity $Ia = \frac{100\,(PET-AET)}{PET}$	Moisture Index MI=Ih-0.6 Ia	Summer need	Climatic type2/
Inches	Inches		Inches			Percent	
11.34	--	--	5.23	31.6	- 19	77	$C_1C'_1dc'_1$
17.71	1.02	5.5	0.77	4.2	+ 3	74	$C_2C'_2rc'_2$
20.59	29.25	138.9	0.47	2.2	+137	70	$AC'_2rc'_2$
22.68	16.56	72.1	0.28	1.2	+ 71	67	$B_3B'_1rb'_1$
22.56	60.30	266.8	0.04	0.2	+267	68	$AB'_1rc'_2$
19.80	87.10	439.9	0	0	+440	72	$AC'_2rc'_2$
19.80	114.35	577.5	0	0	+578	72	$AC'_2rc'_2$

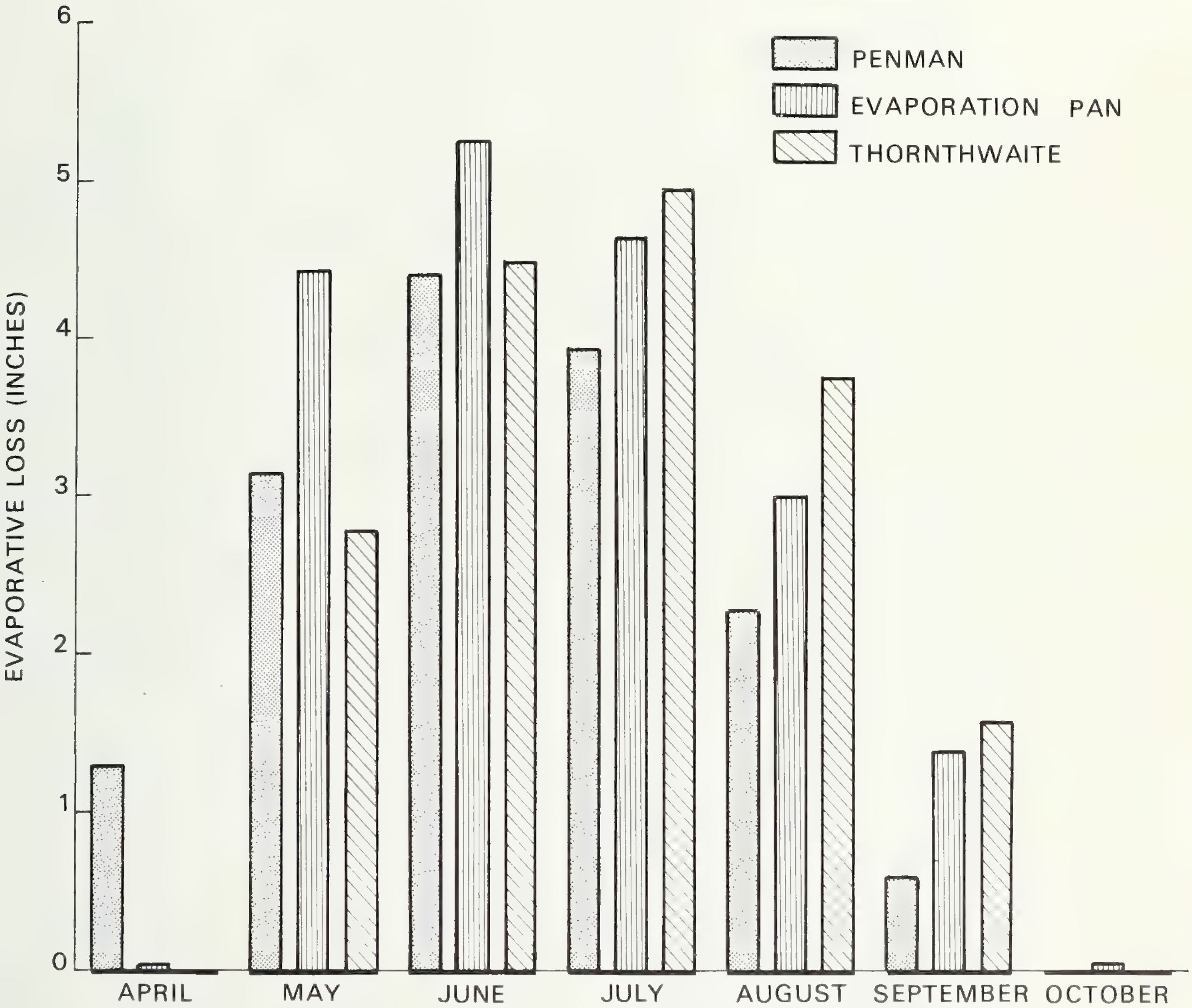

Figure 2.--*Estimates of potential evapotranspiration for University Experiment Station near Fairbanks, Alaska. Results by these three widely used methods are based on not less than 10 years of average monthly climatic data. This is the only station in Alaska for which long-term data are published to make this comparison possible.*

duration, and sometimes of questionable quality. Comparisons of PET were possible between 22 high-elevation stations and nearby sea-level or valley-bottom stations. Differences between PET and elevation for these stations are plotted in figure 4. The line drawn through these plotted points suggests that PET decreases about 1 inch per year per 500 feet of elevation.

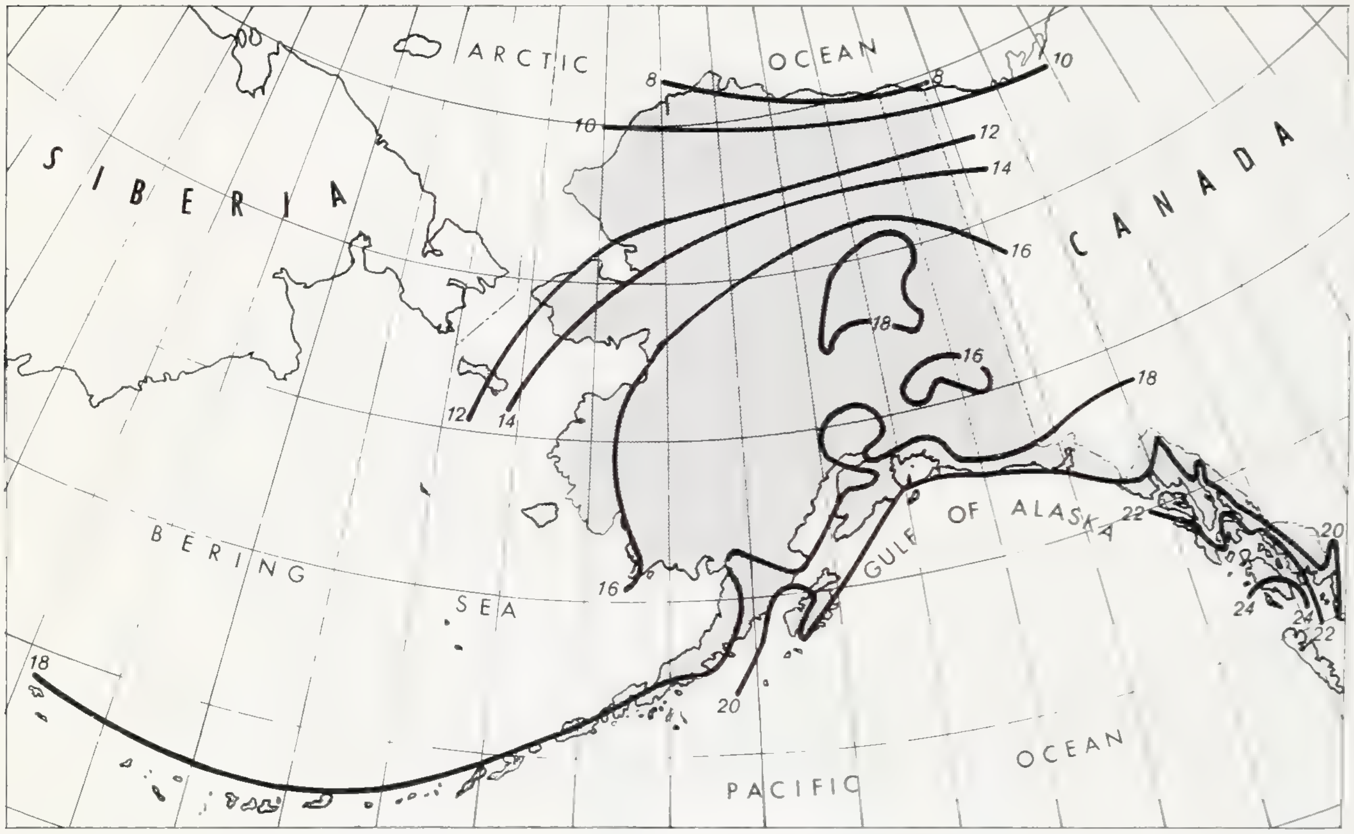

Figure 3.--*Potential evapotranspiration (PET) in Alaska. These lines, showing yearly evaporative loss in inches, are based solely on valley and sea-level climates.*

DISCUSSION

These estimates of PET must be considered first approximations which will be improved as better equations are developed to make more effective use of improved, more abundant, climatic data.

The influence of elevation on PET needs clarification, especially in a State as mountainous as Alaska. The hills and mountains of the interior are not represented in figure 3 because most interior climatic stations are along major rivers and represent only valley climates. The only stations reporting climatic data at high elevation in the interior (Summit Nike Site and Bonanza Mine) suggest a perhumid tundra climate above approximately 4,000-foot elevation. This climate is sufficiently wet and cold to nourish glaciers, which abound in the Alaska Range but which are smaller and occur less frequently in the drier climate of the Brooks Range. For coastal Alaska, the data in table 1 describe only stations near sea level and below the 3,000-foot timberline. Permanently snowcapped, extensively glacierized mountains also evidence a cold, wet climate at high elevation which is wholly unrepresented in figure 3.

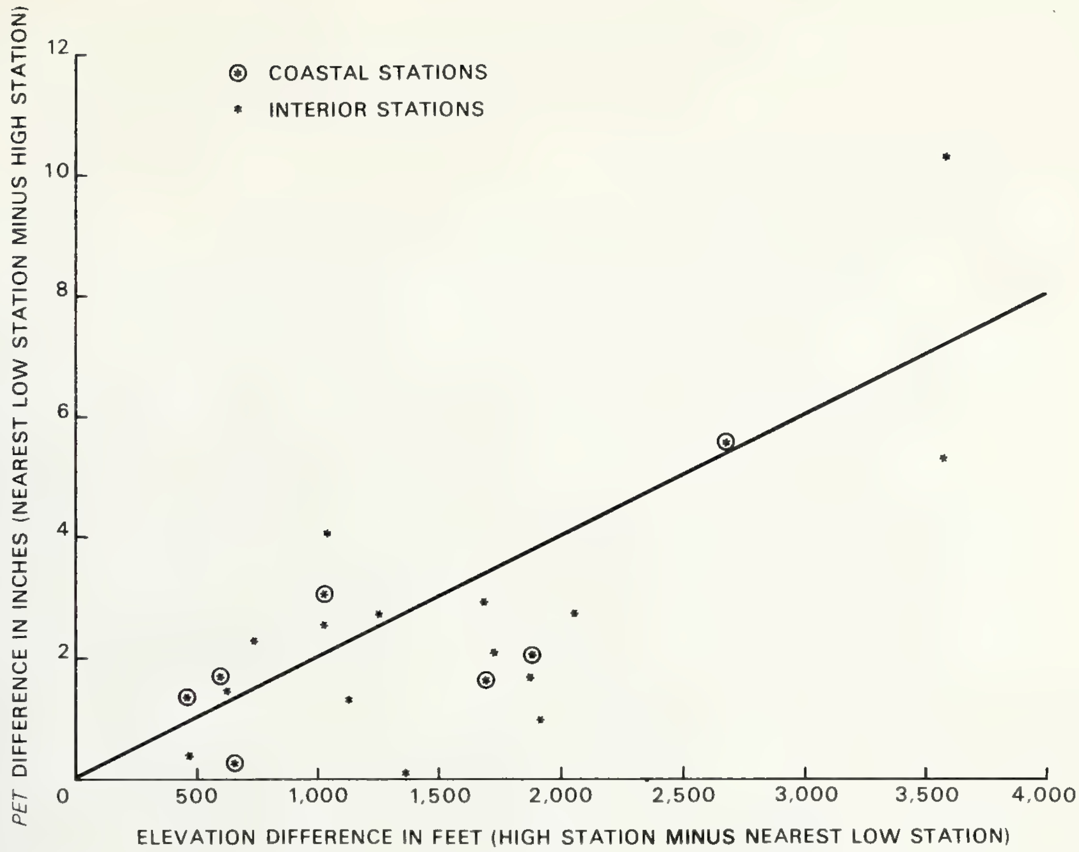

Figure 4.--*Effect of elevation on potential evapotranspiration (PET). Each plotted point shows how PET decreased with increasing elevation at the 22 stations where this comparison was possible. The 2:1 line was not statistically fitted to the data.*

The suggestion that PET decreases about 1 inch per year per 500 feet of elevation cannot be checked in the literature. There are, however, many studies of elevation-temperature relations and Thornthwaite's method of computing PET is based solely on temperature. It is an ecological truism that temperature on mountains decreases about 1° F. per 300 feet of elevation. Spurr (1964), for example, reported that temperature on east coast mountains decreases 3° F. per 1,000 feet of elevation. In maritime California, this increase is only 1° to 1-1/2° F. per 1,000 feet of elevation, a modifying effect of onshore Pacific winds. Table 1 permits similar temperature comparisons of Anchorage to Summit Nike Site, Kennecott to Bonanza Mine, and Valdez to Thompson Pass. These comparisons show average annual temperatures decreasing 1° F. per 370 to 650 feet of elevation. Because our temperature-elvation relations concur with those from other parts of the country, the PET-elevation relation suggested in figure 4 is at least of the correct magnitude.

Ideally, natural vegetation should reflect local climatic influences. For example, Thornthwaite and Mather (1955) demonstrated a close correlation of natural tree and grass vegetation to the moisture index along the 41st parallel in the United States. Hare (1950) reported no obvious correlation between

moisture provinces and forest divisions of the subarctic Labrador-Ungava Peninsula. Eastern Canada, however, does not have the large differences of rainfall found in Alaska. A belt of heavy rainfall extends along the southern shoreline from British Columbia westward to the end of the Aleutian chain. Within this fringe of perhumid climate, a dense western hemlock-Sitka spruce forest extends west to the Kenai Peninsula. Southwest from the Kenai Peninsula, Sitka spruce extends to Afognak Island and is invading Kodiak Island. Within this forest region, average PET for 68 stations is 21.27 inches, with a standard deviation of ± 1.61 inches. A few plantations of Sitka spruce on the Aleutian Islands have survived but they have grown very slowly. Note in table 1 the similarity of climate on Afognak, where Sitka spruce thrives, and on Adak, where one of these abortive plantations still exists. Our data suggest that failure of the coastal forest to thrive west of existing boundaries must be explained in terms other than temperature or amount and distribution of precipitation.

Heavy precipitation along the coastal perhumid belt becomes much lighter within relatively short distances from the Pacific Ocean, as shown in the following comparison of paired stations:

Precipitation at stations having perhumid climate	Precipitation at nearest station in drier climate	Distance apart
(Inches)	(Inches)	(Miles)
158 (Chignik)	17 (Port Heiden)	45
164 (Whittier)	14 (Anchorage)	50
89 (Thompson Pass)	21 (Teikel)	35
61 (Haines)	21 (Klukwan)	25
51 (Eldred Rock)	11 (Atlin)	70
80 (Alice Arm)	19 (New Hazelton)	85

In forested areas, this transition from heavy to light precipitation is distinctly marked by a change from western hemlock-Sitka spruce to the spruce-birch-aspen forest of the interior. Commercial stands of this interior forest are found along most major streams east of longitude 160° W. and south of the Arctic Circle (Hutchison 1967). Although annual precipitation rarely exceeds 15 inches, and may be as low as 6 inches within the commercial forest region of the interior, PET in this region ranges from 15.5 to 19.8 inches. Commercial timber, much of which occurs along major rivers (Hutchison 1967), may use moisture from water tables in addition to local precipitation for their water supply. These observations seem to be consistent with the widely accepted view (Hare 1950) "that the northern forests are governed in their growth by temperature and that precipitation is everywhere adequate to supply the needs of the growth possible under such cool conditions." Nevertheless, annual rings of reduced width occur[7/] that superficially appear to be associated with the

[7/] Personal communication from Wilbur A. Farr, Research Forester, Institute of Northern Forestry.

record low precipitation during 1958 and other dry years. However, the relation of growth ring width to various site factors, including precipitation and temperature, is poorly understood in the interior. Spruce-birch-aspen forests exist where PET is as low as 14 inches per year but rarely in commercial stands and usually associated with tundra vegetation. In fact, tundra mixed with scrubby tree cover should be expected wherever annual PET is less than 16 inches. These observations are consistent with Hare's findings for eastern Canada (Thornthwaite and Mather 1955) as shown in table 2.

Table 2.--*A comparison of potential evapotranspiration in natural vegetation of eastern Canada and interior Alaska*

Vegetation type	Potential evapotranspiration	
	Eastern Canada	Interior Alaska
	- - - - - - - - Inches - - - - - - - -	
Tundra	12.2	14.52 ± 2.42[1/]
Mixed tundra and noncommercial forest	12.2 - 16.5	16.51 ± 1.49
Commercial forest	16.5	17.76 ± .86

1/ Mean and standard deviation for all stations.

Perhaps the higher PET values for Alaska are due to the aforementioned bias in station location, although ocean currents, topography, and prevailing airmass genesis actually may cause an Alaskan climate warmer than that of the eastern part of the continent at the same latitude.

More refined statistical treatment seems unwarranted since these data were collected over varying timespans by hundreds of observers having different equipment and training. Studies specifically designed to correlate vegetation and climate probably will relate natural plant cover to PET more as reported for eastern Canada.

Funsch (1964) used 16-year mean temperatures to derive growing season distribution of degree-days for 22 stations in the commercial forest zone of interior Alaska. PET calculated for the same stations also was derived from mean temperatures but from records collected over varying spans of time. To test the influence of timespan on temperature records, temperatures used in the PET calculations were converted to degree-days. Funsch's mean for all stations was 1,430 degree-days, a value little different from 1,438 for the same stations derived from PET temperature data. Although varying lengths of record had little effect on the degree-days, PET was much less variable as an

index of climate. For the 22 stations, coefficient of variation averaged almost 20 percent for growing season degree-days, a little over 5 percent for annual PET. Thus, even though temperature is recognized to govern growth of northern forests, PET reflects forest distribution better than temperature data alone.

An interesting anomaly occurs along the Arctic coastal plain where evaporative demand considerably exceeds precipitation but soil almost always remains wet, even saturated, throughout the short summer. The moss and lichen plants of this tundra region apparently use water at slower rates than does vegetation of warmer regions. Tundra plants function more like mulch than like transpiring vegetation, and under these conditions the whole Thornthwaite formula seems to break down.[8/] Shallow thawing of permafrost under the tundra vegetation also may contribute moisture to these very wet soils.

The few checks available suggest that PET by Thornthwaite's method provides valid estimates of this measure of climate. Our evidence supports Hare's (1950) conclusion that growth of the northern forest is governed by temperature. In terms of thermal efficiency, commercial forest can be expected in warm microthermal climates, whereas noncommercial forest mixed with tundra can be expected in cold microthermal climates. Forest species, if found at all in tundra climates, are severely stunted. These close relationships of natural vegetation to the Thornthwaite climatic classification strengthen our confidence in PET as a key parameter of climate.

[8/] Personal communication from John R. Mather, President, C. W. Thornthwaite Associates, Centerton, N. J.

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